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Economic analysis of understanding and implementing design criteria for acoustic suppression in military residential units

Stader, James F.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

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Imlementing Design Criteria for Acoustic
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by

James F. Stader

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Economic Analysis of Understanding And Implementing Design Criteria for Acoustic Suppression in Military Residential Units

by

James F. Stader
Lieutenant, Civil Engineer Corps, United States Navy
BSCE, Virginia Military Institute, 1983

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis examined and analyzed the Navy Military Housing acoustical design practices and procedures for military residential housing. The Uniform Building Code and Naval Facilities Engineering Command (NAVFACENGCOM) Instruction 11101.85 were used as base line guidance for design and construction of Navy Family Housing Projects. NAVFACTENGCOM's design process was first examined to determine if more emphasis should be placed on noise suppression in Navy Family Housing. Based on the analysis, it was determined that the Navy Family Housing Program does address the design for noise suppression through the use of pre-established and factory tested Sound Transmission Class (STC) assemblies. However more emphasis should be placed on the acoustic evaluation process after a contractors' design is received for evaluation.

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I. INTRODUCTION

A. GENERAL

This thesis examines the Naval Facilities Engineering Command's (NAVFAC) existing acoustic design practices and procedures for all Navy Family Housing Construction Projects. Because family housing is considered an important benefit for all service members, this thesis examines whether or not NAVFAC is producing public housing in a form that reflects the end users estimated benefits of additional sound suppression.

Acoustic privacy in rooms and dwelling units gained by sound insulation is no longer considered a comfort item or amenity of life by the U.S. population. Home and apartment residents have come to view quiet interior living as a needed environment to assure their mental well being. Because 1.) noise cannot be seen and can be eliminated by turning off the source, and 2.) the full effects of noise on human beings is still open to question, noise protection has not received the social concern that has been given to air and water pollution. [Ref. 11]

To stimulate the concern, the National Environmental Policy Act of 1969, the Environmental quality Improvement Act of 1970, and the Noise Control Act of 1972 were established to identify problems of noise abatement in the United States. [Ref. 17] According to Section 2 of the Noise control Act,

"Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health and welfare." [Ref. 17:pg. 268] For this reason, Environmental Impact Statements are now required for all new construction, relocation projects or rehabilitation work.

While in theory this was considered a large step towards making the construction industry aware that noise protection for dwelling end users is a must, the building industry and consumers recognize that the place of human habitation, whether a simple hut or a modern villa, is essentially a weather-protective shelter. [Ref. 16] For this reason, the design of a domicile in a form of a weather-resistant and stable structure is the major public concern. [Ref. 16:pg. 155] This can be witnessed by the structure of our existing building codes and the lack of acoustic attenuation in the codes.

In many European nations, building codes include acoustic insulation requirements, in addition to those aimed at sanitation, fire protection, heating, ect. Construction in the United States however, is regulated only to ensure that the protection of life and property is maintained for individuals that own or use a constructed facility. All construction in the United States, whether it is on the federal or state level, is regulated by some type of building code or building guide specifications. Building codes and DOD

specifications are a culmination of regulations and practices that have evolved over the years to help direct construction efforts.

A building code is a legal document which sets forth requirements to protect the public health, safety and general welfare with respect to the construction and the occupancy of buildings and structures. [Ref. 1] In doing so, codes generally set forth requirements for testing, fire protection, structural design, fire resistent and structurally sound materials. Energy conservation has only recently been included in the scope of building codes.

Standards are developed, not only to help produce quality products, but to continuously remind designers, engineers and contractors of the high priority that must be assigned to safety. In particular, designers must keep in mind the safety of occupants after the residential units are complete.

Requirements for noise suppression for buildings vary with location of the facility, noise generation and frequency. The acoustical requirements within buildings are a compilation of standards often produced by the American Society for Testing and Materials (ASTM).

An ASTM standard represents a common viewpoint of those parties concerned with its provisions, namely producers, users, consumers, and general interest groups. [Ref. 19] It is intended to aid industry, government agencies and the general public. The use of ASTM standards is purely

voluntary. It is recognized that, for certain work or in certain regions, the specifications may be either more or less restrictive than needed. The existence of these standards does not preclude anyone from manufacturing, marketing, or purchasing products, or using procedures not conforming to the standards. [Ref. 19:pg. iv] NAVFAC is one of the government agencies that uses ASTM standards for military construction. When used in the design or construction phase, NAVFAC references applicable standards that a contractor must follow in order to maitain minimum quality. Appendix (A) shows ASTM acoustic standards that are presently available and can be referenced for DOD construction work. [Ref. 4]

Standards from the National Acoustical Society are not referenced in this thesis because NAVFAC does not use any guidance or material from the society. While ASTM standards provide guidance for acceptable noise transmission criteria, compliance with these standards is accomplished by using field or factory tested assemblies which come from pre-established building catalogs, such as the Sweets Building Catalog or the Architectural Graphic Standards guide.

1. Pre-Estalished Building Catalogs

Pre-established building catalogs are publications that list construction products from various companies. Publications list the products name, general information about the product, what it is used for, how it is assembled and how much it costs. Additionally, they provide available test data

including what test standard the product was measured against and the test results. They also identify the testing lab and test date.

A common standards catalog, that is widely used for general building and renovation, is the Sweets Catalog file, published by the McGraw Hill Information Systems Company. The catalog lists products that are available to the construction industry and its' manufacturers. The catalog is broken down into seventeen different construction activities for easy identification. (See Table I) In each activity, the number (e.g.,5) represents the activity and the name (e.g., metals) represents the construction discipline. [Ref. 2]

TABLE I
CONSTRUCTION DISCIPLINES

_ Special Design	6 Wood/Plastic	11 Equipment
1 General	7 Thermal	12 Furnishings
2 Sitework	8 Doors/windows	13 Special Construction
3 Concrete	9 Finishes	14 Conveying Systems
4 Masonry	10 Specialties	15 Mechanical
5 Metals		16 Electrical

The seventeen activities are further broken down into specific sub activities within the discipline. An example of a sub activity in activity 9, (Finishing) is sub activity 09550/AME. This lists assemblies for overhead floor

construction and the Sound Transmission Class (STC) ratings for each type of floor construction. (Appendix B)

2. State And Local Codes

While performing thesis research, the question was whether local building codes for noise suppression were incorporated into NAVFAC design criteria. While local and state codes are reviewed and researched, discussions with NAVFAC state that all federal facilities exceed state and local codes. Because federal standards and specifications for Navy Family Housing Projects exceed state and local codes, the state is not involved during the design phase of Navy family housing.

While state codes are not referenced in the design stage, the Uniform Building Code (UBC) is referenced. Designers of Navy housing however, only reference this code to pick up any construction discipline that may have been overlooked during the design stage. DOD standards are the focal point for designs, the UBC code is used indirectly as a reference.

While NAVFAC does not reference any state or local acoustic codes, many states and local governments have established acoustic codes. An example of this is the state of California. The Uniform Building Code is the primary code that regulates all building construction in the state of California. The State of California, however, has adopted an additional code, the California Administrative Code. This

specifies the same Sound Transmission Class (STC) ratings for walls and floors as the UBC, but specifies additional requirements that are not outlined in the UBC. [Ref. 16:pg. 34]

One of the additional codes is the requirement to specify an interior Community Noise Equivalent Level (CNEL) of 45 dB. This is the interior noise level that must be obtained inside a dwelling unit after the construction has been completed. It is important for builders and designers to secure an evaluation of the exterior CNEL at the prospective site so that the exterior walls, windows and roof may be adopted which can lead to the specified interior noise climate. [Ref. 16:pp. 34-40] In addition to this state requirement, local governments have the option of taking the UBC or state codes and modifying them to meet particular standards for a certain city. An example of this is the Los Angeles Building Ordinance No. 143, 363. This ordinance calls not only for party walls to have a lab tested STC rating of 50, which is required by the UBC and the California Administrative Code, but also requires that all walls that separate units from garages and units with corridor partitions to also have lab tested STC ratings of 50. [Ref. 16:pg. 35]

B. BACKGROUND

Service members and designated federal employees living in Navy Family Housing units many times encounter the displeasure of hearing externally and internally generated noise. Current

studies of the effects of noise show that people repeatedly exposed to typical city noise levels exhibit increased irritability and discomfort, severe nervous tension, loss of ability to concentrate, and loss of sleep. [Ref. 11] Effects of noise intrusion can be considered under a variety of headings. The three most recognized effects are: [Ref. 17:pp. 123-126]

1. Physical in the sense that a person's hearing becomes damaged when the occupant is prolongedly exposed to sounds of high intensity.

2. Physiological-noise produces a change in body activity (noise cannot only restrict intestinal motion, but cardiac activity).

3. Emotional-generally in a form of annoyance or irritation.

Interruptions, anxiety, and feelings of frustration impair aptitude to perform even simple tasks. Because of these problems and effects caused by noise intrusion, occupants question the acoustical integrity of the units. While residents are aware that insulation and building material composition is considered for thermal conditions, occupants wonder if the construction materials are designed to suppress noise. Residents wonder if designers consider noise suppression at all.

To properly address this program, the NAVFAC has taken a more active role in the procurement and design of military housing. Prior to Turnkey design, housing designs were typically developed by government in-house civilian personnel in one of the seven Engineering Field Divisions (EFD). Over

the past 20 years, the emphasis has been to procure family housing units through the use of Turnkey design procedures. Turnkey design is a plan that is forwarded to NAVFAC by a civilian construction firm. The plan outlines a particular design for potential Navy housing. The design is in response to a government Request for Proposal (RFP). (Appendix C) The design is developed by the contractor at his own expense with the hope that the company will be selected to build the housing project for the government. The design shows how the product will look and how much it will cost. The background and procedures for the Turnkey process are discussed in Chapter III.

Quality designs are a top priority for the Navy family housing program. Thus, NAVFAC uses various design standards to ensure that all facets of noise suppression within family housing are addressed. These relationships range from site selection and environmental effects, to health and comfort requirements. This thesis examines the role of the design stage in providing acoustical suppression, and outlines recommendations about NAVFAC's efforts to identify noise suppression requirements.

C. METHODOLOGY

This thesis was conducted using archival and opinion research to determine whether NAVFACENGCOM identifies noise suppression design requirements for family housing, and how

these requirements are incorporated into the construction phase. In particular, this thesis focuses on these questions:

1. Can Department of Defense housing be built in any particular location irregardless of existing noise conditions?

2. Does NAVFACENGCOM use the Uniform Building Code?

3. Does the Uniform Building Code sufficiently address noise suppression and does it meet NAVFAC's requirements?

4. Does NAVFAC have standards, military specifications and housing design handbooks to address noise suppression?

5. How are residential units designed once standards and sound transmission class ratings are identified?

D. SCOPE, LIMITATIONS AND ASSUMPTIONS

The scope of this thesis is limited to examining and analyzing NAVFAC's noise suppression design development for the Navy Family Housing Program. Research covered the analysis of the Uniform Building Code, NAVFAC Inst. 11101.85, the Navy housing manual and other applicable design handbooks and references. Personal interviews of NAVFAC personnel were limited to the users within Western Division, Naval Facilities Engineering Command and Naval Facilities Engineering Command, Washington DC. Phone interviews concerning the integration of the UBC code with current NAVFAC standards and practices were limited to agents of OSD and NAVFAC. It should be noted that local and state code requirements are not addressed in this thesis because gathering sufficient information from local and state building officials and organizations is beyond the scope of this thesis.

The assumptions that need to be addressed are as follows:

1. The reader has a working knowledge of NAVFAC construction procedures and practices.

2. The reader is not familiar with acoustic noise suppression terminology.

3. The reader is not familiar with NAVFAC noise suppression design requirements, planning criteria or Turnkey housing.

To determine whether NAVFACENGCOM is designing public housing with appropriate acoustic quality characteristics, Chapter Two examines the background of noise suppression.

E. DEFINITIONS & ABBREVIATIONS

SOUND PRESSURE LEVEL (SPL)- average pressure level of sound waves at a particular point, equal to 20 times the log of the measured pressure divided by the referenced pressure, which is 20 micropascals. SPL=20log(pressure/ref. pressure) [Ref. 3]

DECIBELS(dB)- sound pressure levels (SPL) are measured in units of decibels (dB) which is a logarithmic rather than a linear scale. It is a unit for measuring loudness of sound. Range extends all the way from a faint rustle of leaves to the roar of jet engines. (1dB-140dB) An increase in 3dB is barely perceptible. An increase of 5dB is clearly noticeable, an increase of 10 dB doubles the volume, and an increase of 20 dB quadruples the volume. [Ref. 3:pg. 5]

SOUND TRANSMISSION CLASS - a term originated by ASTM to provide a single number rating system for insulation of common building materials, compound structures, doors, windows, ect. It is also intended to overcome certain inadequacies developed when the sound attenuating quality of a space divider was expressed as the numerical average of its transmission losses at but a few frequencies. [Ref. 16:pg. 38]

Architects call for a minimum insulation characteristic and generally specify a wall with a greater insulation capability than apparently required, to include estimated field losses, poor workmanship, improper or imperfect materials, ect. A STC 30 contour (See Figure 1) to the designer means that a sound transmission loss of 30 dB was experienced for a particular material or assembly at a

frequency of 500 Hz. [Ref. 16:pg. 39] The reason why the 500 Hz frequency is used has to do with the capability of the human ear. The frequency over which the ear is most sensitive is from 800 Hz to 6000 Hz. This range corresponds to the good impedance matching between a persons outer ear and the air. Poor impedance matching between the outer ear and the air occurs at frequencies below 400 Hz. Because of this, the threshold of hearing becomes quite high at frequencies below 500 Hz. [Ref. 19:pg. 453]

A reference curve is developed by taking a material and testing it to determine the transmission loss (tl) in decibels at 500 Hz. This transmission loss value in dB is the base point for which a reference curve is constructed. The reference contour is graphically sectioned into three five one-third octaves. The first five one-third octaves will have a slope of 9 dB/octave and its frequency range will go from 125 Hz to 400 Hz. The second five one-third octave will have a slope of 3 dB/octave and its range will be from 400 Hz to 1250 Hz. The final five one-third octave will have a zero slope and its range will be from 1250 Hz to 4000 Hz.

Figure 1 shows that a material tested at 500 Hz had a transmission loss of 30 dB. Using this reference point, the second five one-third contour line will be constructed first. After using a slope of 3 dB/octave, the two other sections of the contour can be constructed. [Ref. 16:pp. 40-43]

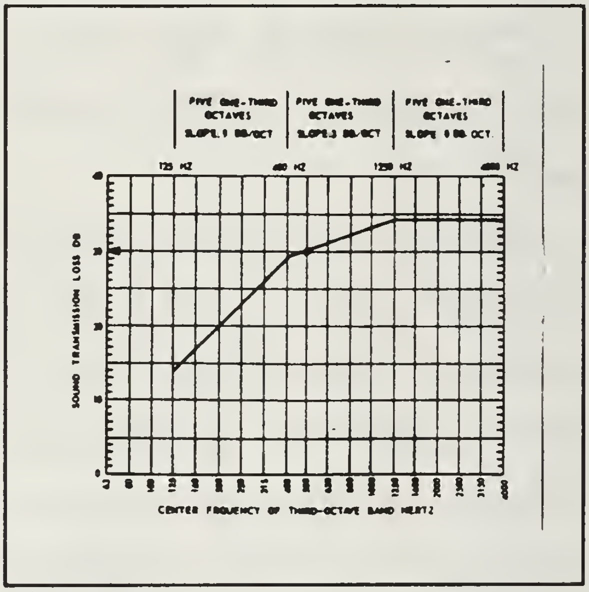


Figure 1

To determine the STC of an actual wall assembly, the measured transmission loss values in the contiguous sixteen one-third octaves frequency bands with center frequencies between 125 Hz - 4000 Hz are compared with the values of the STC reference curve according to the following conditions. (See Figure 2)

1. A single unfavorable deviation frequency transmission loss value which falls below the contour may not exceed 8 dB.

2. The sum of the unfavorable deviations falling below the reference contour shall not exceed 32 dB. [Ref. 19:pp. 319-321]

The STC rating of a partition is the numerical value which corresponds to the TL value at 500 Hz for the highest reference contour for which the two above conditions are simultaneously met. The below example is used to show the above procedure. The TL values are plotted on Figure 2 and graphed against a STC reference curve of 47. The TL values represent the transmission loss in decibels that was witnessed during the test phase of a particular material.

FREQ-Hz	124	160	200	250	315	400	500	630	800	1000
TL-dB	24	27	33	38	41	45	45	46	48	48

FREQ-Hz	1250	1600	2000	2500	3150	4000
TL-dB	51	56	54	55	58	64

The data is plotted in Figure (2). The maximum deviation from the reference curve is 6 dB at 125 Hz. The sum of the deviations below the reference curve is 26 dB. [Ref. 18:pg. 320] Since both conditions were met, the assembly tested will have a STC rating of 47. If the designer had tried to use a reference curve with a STC of 48, the sum of the unfavorable deviations would have been 37 dB, which exceeds the 32 dB threshold. Because the designer knows this, the designer knows that the maximum STC rating for the particular assembly is 47.

IMPACT ISOLATION CLASS(IIC)- a rating system for floor impact noise. Higher rating indicates improving performance. Impact noise on floors is rated by testing with a standard tapping machine and measuring the noise level below. Appendix D illustrates typical construction types and respective IIC ratings. [Ref. 3:pg. 26]

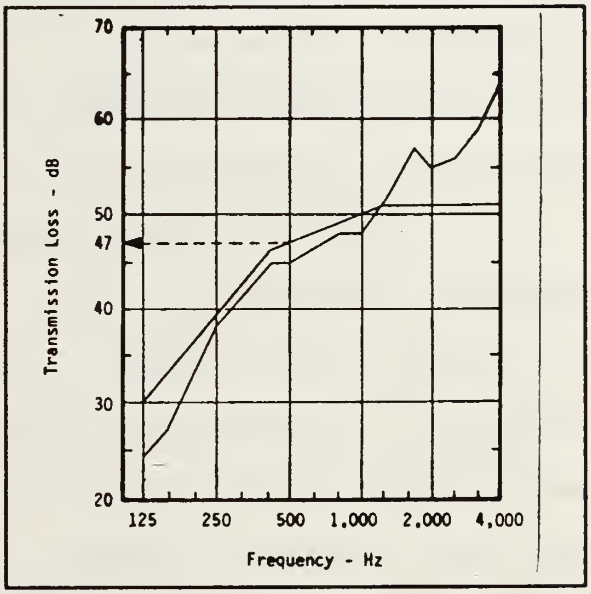


Figure 2

SOUND ABSORPTION COEFFICIENT- percent of sound absorbed by a material. Ideally, the fraction of the randomly incident sound power absorbed or otherwise not reflected.

REQUEST FOR PROPOSAL(RFP)- government solicitation to contractors and designers requesting a design and/or a quote to perform some particular work.

LEVEL DAY NIGHT(Ldn)-the energy equivalent weighted continuous sound level compared to a 24-hour varying noise level, with a 10 dB penalty added to night time noise levels between 10 pm. and 7 am. this is measured by using an integrating sound level meter. [Ref. 3:pg. 2]

II. THE NEED OF PROVIDING PROTECTION

A. BACKGROUND

In Family Housing Projects, poor sound privacy and noise suppression between units is a pervasive problem that is almost impossible to address once the particular dwellings are constructed. Only large expenditures seem to correct any acoustical deficiencies once the dwellings are complete, and even then, this is not always cost effective to try to correct. Current building codes, such as the Uniform Building Code, Basic National Building Code and Standard Building Code include only minimum standards to ensure that sound insulation requirements are met. In short, the three building codes that are presently used in the United States only give lip service to the problem. This offers little assurance to potential investors in luxury family housing projects. [Ref. 5]

Because there is a lack of noise suppression standards within the three codes, NAVFAC is taking a key interest in providing minimum noise standards that benefit the military end user. Noise suppression in the construction industry has changed over the past 20 years. NAVFAC recognizes that the noise problems military members experience in their residential units are created by overlooking or underestimating noise sources.

In order to see why NAVFAC is taking an aggressive and positive approach to increasing noise suppression, this thesis first reviews past events and current problems which have magnified the problem to its current level.

B. GENERAL HISTORY

The requirement for noise suppression, while relatively new to the United States, was first addressed and presented to the European community just before World War II. Germany in particular established crude field tests, though effective for the time. These tests measured the insulation requirement for walls and floors by using an airborne insulation index. [Ref. 6 and 7] This first measure paved the way for the European community to establish national noise suppression codes that are still in force today.

While most of the world's major nations use established noise standards outlining minimum requirements for suppression and protection, the United States has not adopted a national standard. The 1960's was a time of broad architectural achievement in every facet of building activity. While significant activity in the American construction industry was going on, there was absolutely nothing being done about acoustical treatment. Of all the complaints owners expressed about family dwellings, the lack of sound proofing generally headed the list of complaints. It is unfortunate that the general public commonly equates a noisy unit to poor quality

construction. For the most part, this is far from the truth. [Ref. 10]

1. Federal Government History

In Europe, the amount of noise reduction between adjacent homes, apartments, and hotels to provide satisfactory quiet enclosures is specified in national building codes. While there is nothing found in the U.S building codes, the American Public Health Association has made similar recommendations to those of the European community. [Ref. 16:pg. 51]

The American Public Health Association recognizes three classes of building construction- minimum, standard and optimum. The Public Health Organization defines the three grades of building construction as follows: [Ref. 16:pp. 51-52]

> **Minimum**-"livable conditions below which occupants risk impairment of privacy, comfort, health and sleep owing to noise, and is to be tolerated only as a lower limit enforced by cost limitations."
>
> **Standard**-"recommended minimum conditions for normal living, and a justifiable standard for all new construction."
>
> **Optimum**-" desirable conditions for living with greatest possible freedom from noise disturbances by providing expenditure, and a level above which additional control is a luxury."

Table 3 provides the three grades M, S, O described above with recommended average noise reductions between 125 Hz - 2000 Hz for various types of walls. [Ref. 16:pg. 52]

TABLE 3
NOISE REDUCTION

	Noise Reduction, dB		
	M	S	O
Through party walls between living room of one dwelling and living room or bedroom of adjacent dwelling	40	50	55
Through party walls between all other combinations of spaces in adjacent dwellings	40	45	50
Through all party floors between adjacent dwellings	40	45	50
Between rooms within dwelling if privacy is expected between these rooms	30	35	45

The first American code established minimum noise standards in 1963 (Minimum Property Standards, MO 2600). The Federal Housing Administration (FHA) set minimum requirements for the control of both impact sound transmission and airborne sound. [Ref 6:pp. 4-43] In 1967, the U.S. Department of Housing and Urban Development (of which FHA is a part) adopted a set of recommendations for the control of airborne noise and impact noise. (Guide to Airborne, Impact and Structure-Borne Noise control in Multi-Family Dwellings) [Ref. 6:pp. 4-43 and Ref. 16:p. 52] The Guide established three different grades of acoustic environments to deal effectively with the wide range of geographic location, urban development and economic conditions.

a. **Grades**

Grade I is applicable primarily in suburban residential areas. (i.e. "quiet" locations where the night time exterior noise levels might be 35-40 dB or lower.

Grade II is applicable to the residential urban and suburban areas with an "average" noise environment. Night time levels might be 40-45dB.

Grade III is considered minimal recommendations and are applicable in "noisy" urban areas. Here night time exterior noise levels might exceed 55 dB.

Designers of housing projects and single homes were required to anticipate, if possible, in which grade the new project would be built. After the acoustical environment was determined, designers were required to provide noise protection in accordance with the HUD guideline for family dwellings. To ensure that designers were designing for acoustic protection in accordance with the new Guide, designers were not provided FHA loans or mortgages until this criteria was shown in the residential design. If the noise criteria was in the design and the builder met all other financial conditions, the FHA loan or mortgage was then approved.

Table 4 lists the criteria for airborne sound insulation of wall partitions between dwelling units for the three different grades. These values represent the minimum standards a designer must design to ensure that the end user would receive some acoustic protection from external noise. The location of the partition (e.g., Bedroom to Bedroom) in Table 4 tells the designer that the exterior partition wall

between two bedrooms of different units must provide a reduction of 55 (dB) (e.g., Grade I).

TABLE 4
PARTITION BETWEEN DWELLINGS

	Grade I	**Grade II**	**Grade III**
Apartment A to Apartment B	**STC**	**STC**	**STC**
Bedroom to bedroom	55	52	48
Living room to bedroom	57	54	52
Kitchen to bedroom	58	55	50
Bathroom to bedroom	59	56	52
Corridor to bedroom	55	52	48
Living room to living room	55	52	48
Kitchen to living room	55	52	48
Bathroom to living room	57	54	50
Corridor to living room	55	52	48
Kitchen to kitchen	52	50	46
Bathroom to kitchen	55	52	48
Corridor to kitchen	55	52	48
Bathroom to bathroom	52	50	46
Corridor to bathroom	50	48	46

When designing for individual units, HUD required designers to provide design criteria for partitions between rooms in the same dwelling. Table 5 lists the criteria for airborne sound insulation within a dwelling unit for the three different grades. [Ref. 6:pp. 4-43 and Ref. 15] [Ref. 16] The tables' line entries state that if a wall falls between two rooms, (e.g.,bedroom to bedroom) the designer must provide a wall design that will provide sound insulation for the particular grade (e.g., Grade I, STC 48).

TABLE 5
PARTITION BETWEEN ROOMS

	Grade I STC	Grade II STC	Grade III STC
Bedroom to bedroom	48	44	40
Living room to bedroom	50	46	42
Bathroom to bedroom	52	48	45
Kitchen to bedroom	52	48	45
Bathroom to living room	52	48	45

TABLE 6
LOCATION OF PARTITION

	STC
Living unit to living unit, corridor(1), or public space(2)	45
Living unit to public space and service areas (high noise)	50

LOCATION OF FLOOR-CEILING

	STC	IIC
Floor ceiling separating living units from other living units, public space or service areas	45	45
Floor ceiling separating living units from public space and service areas (high noise) including corridor floors over living units	50	50

In 1976, HUD revised the 1963 FHA report, paying more attention to one and two bedroom units. [Ref. 6] In particular, the revised report provided noise protection to dwellers from noise generated from public spaces such as service areas and corridors. It also addressed noise design levels for floor-ceiling applications. (See Table 6) Not only would the designer have to provide sound insulation for a floor-ceiling assembly, but impact criteria was also required.

In the early 1980's, the revised 1963 FHA report and the HUD guide for multi-family dwellings was no longer given a high priority by the federal government. The national level of attention that acoustical design practices was starting to receive was to become the responsibility of state and local governments. Because the federal government, in particular the FHA, was no longer reviewing a builders design for a loan or mortgage approvals, the building industry no longer had an incentive to put acoustic suppression in the designs unless a particular consumer requested it. The federal government anticipated that states would use existing HUD guidelines and provide additional guidance were needed.

C. EXISTING CODE PRACTICES

Because of the state's newly provided autonomy from the federal government, the states failed to give this matter the priority it needed. The states argued that sound-retardant construction should be left to consumers themselves, like matters of architectural esthetics and climatic comfort. Economic factors should be given chief consideration in selecting the type of wall or partition. [Ref. 17:pp. 167-168]

In order to select the proper type of wall for a construction project, three private organizations establish and publish building codes for the United States. The three organizations cover different geographic regions. The geographic zones are shown in Figure (3). [Ref. 1:pg. 11]

[Ref. 9] While these codes regulate the construction practices for different regions, the requirements of providing adequate noise protection for the end user receive litte attention.

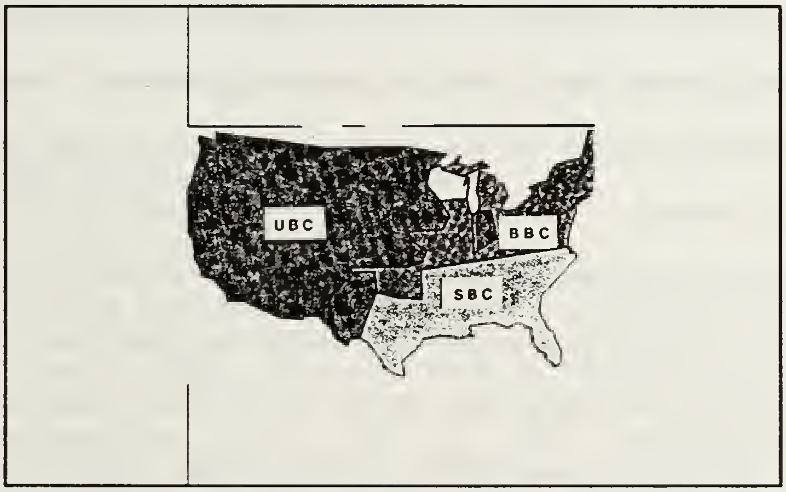


Figure 3
Geographic Zones

1. Organizations and Codes

a. International Congress of Building Officials (ICBO): offers the Uniform Building Code (UBC)

b. The Building Officials and Code Administration International (BOCA): offers Basic/National Building Code (BBC)

c. Southern Building Code Congress International (SBCCI): offers Standard Building Code (SBC)

Because the Federal Administration anticipated that the states would continue to use existing HUD guidelines,

require the builders to specify acoustic criteria to obtain loans, and work with the three building code organizations, they believed that sound protection for the end user would improve. However, since the states did not consider this a vital issue, they did not actively pursue this goal with the three code organizations or the housing loan industry. Sound protection for the end user is actually worse. The shift from a regulated practice to an unregulated practice has decreased the requirement for noise protection. The Federal Administration expected the local authorities to fill the gap. Additional confusion concerning noise protection in the United States arises because the three building codes, which have only minimal noise suppression standards for separating wall and floor assemblies, all specify different acoustic requirements.

The Uniform Building Code offered by ICBO contains minimum standards for separating wall and floor-ceiling assemblies. (STC 50 for factory tested, 45 if field tested. IIC 50 for factory tested, 45 for field tested.) The BOCA Basic/National Building Code however, calls for not less than STC 45 and IIC 45 for wall and floor ceiling assemblies when tested in accordance with ASTM E 90 and E 497. The SBCCI Standard Building Code calls for not less than STC 45 for partitions and walls as tested in accordance with ASTM E 90, but does not have any recommendations for the IIC isolation. [Ref. 9:pp. 3, 4]

Because there are three different Sound Transmission Class (STC) requirements for the United States, NAVFAC takes the approach of requiring that all party walls will have a minimum of STC 55 for Navy Family Housing. All floor-ceiling assemblies will have a minimum of IIC 60. These requirements exceed all present codes, and one STC/IIC design criteria replaces the three different regional requirements.

D. ADDITIONAL HISTORICAL CONCERNS

1. New Technology

As stated previously, building construction technology and methods has rapidly improved during the past thirty years. The implementation and use of new technology within residential units is making the point more direct that noise protection and suppression is a must.

"The crescendo of noise, whether it comes from trucks or jack hammers, sirens or airplanes, shatters serenity and can inflict pain. We dare not be complacent about this ever mounting volume of noise. In the years ahead, it can bring even more discomfort...and worse...to the lives of people." President L. B. Johnson.[Ref. 11:pg. 1]

One adverse result from the increase in modern technology is that it frequently exposes the end user to more noise. Expanded use of aircraft, vehicles and, most importantly, home appliances contribute to the need for greater noise protection requirements. [Ref. 11:pg. 1]

Twenty years ago, residential units were not exposed to garbage disposals, several televisions, washers, dryers and dishwashers. [Ref. 10] In the past, these factors were not considered during the design of family housing.

The increased use of domestic appliances is, for the peace of the home, made much worse by lighter walls, thin ceiling construction, thin non-bearing partitions and other sound transmissive building details. [Ref. 17:pg. 194] This has been brought about partly by 1) the lack of mandatory acoustical criteria for homes in the form of building code restrictions and 2) by even higher construction costs which tempt builders to select cheap, light-weight walls and floor systems. Table 7 provides sound levels for domestic devices that have been developed or improved through technology over the past 20 years. These appliances are commonly found in households today and contribute to our increasing acoustic problems. [Ref. 17:pg. 194]

TABLE 7
EQUIPMENT

	A-WEIGHTED SOUND LEVEL
Electric shaver at 2 in	85 dB-A
Garbage disposal at 2 ft	80
Vacuum cleaner at 2 ft	86
Window Air conditioner at 2 ft	97
Refrigerator at 2 ft	70
Television at 8 ft	70
Food mixer at 2 ft	70
Telephone at 10 ft	70
Sewing machine at 4 ft	66

In addition to new transportation and home appliance technology, the growth of light weight building materials is greatly affecting the residential unit's acoustical integrity. It was structural steel and reinforced concrete that made the sky scraper possible and many say this represents America's gift to architecture. Because of the increasing metropolitan population and the high cost of land and buildings, our residential dwellings have been getting taller with less land available to use.

Because of these taller buildings, designers are forced to use thin metal and glass products for exterior walls instead of solid concrete panels. Concrete is by far the cheapest building material for sound insulation purposes. If thick enough, it can keep out acoustic sounds as well as chemical agents, as in the use of the Survivable Collective Protection Shelters. Concrete has a draw back however, if weight is a priority. The designer is forced to look for an alternative material. When this happens, the switch from concrete to lighter materials becomes objectionably more sound transmissive. Where technology has solved many structural and development problems, new social problems, primarily unwanted noise, have been generated. [Ref. 17:pp. 159-160] Because these developments have led to improper insulation, NAVFAC prefers to use established reputable manufacturing designs and systems, already fielded and factory tested for acoustical performance.

2. Cost

It is quite expensive to design and build a unit with regard for noise attenuating materials. Thinner, cheaper materials do not provide as good a sound barrier as thick, dense materials. [Ref. 12] One of the greatest draw backs in using high density materials is the cost of the materials themselves. A 3/16 inch thick sheet of lead, which displays a high noise reduction characteristic above 3000 Hz, weighs 11 lb/square foot and costs $3.36/square foot. In contrast to this, 1 inch thick stucco with very much the same surface density costs only 3.3 cents/square foot. [Ref. 16:pp. 58-59] One of the reasons that the construction industry uses light weight materials instead of dense materials is the fact that land is decreasing in terms of its availability. [Ref. 11] Because land is becoming a scare good, more expenditures are required to purchase the land. Because land is getting more expensive, consumers have less to spend on homes.

To offset this large cash outlay, lighter and cheaper materials are being used to substitute for denser, better acoustical products in the construction of homes. Because these cheaper, thinner materials are being used, the cost is reduced but the quality of the structure is jeopardized. Because there is less land to build single units, more apartments and condominiums are being built. By providing more apartments and condominiums with light weight, poor sound attenuation materials, the end user of the unit may not

consider the unit desirable to live in and may be forced to look for alternative housing to meet the end users needs.

A designer of a dwelling unit can satisfy a customer's acoustic suppression needs if there is not any financial constraints put on the designer. As previously stated, designing and building with acoustic needs in mind is expensive. To illustrate this, Figure (4) shows a cost relationship of providing noise suppression in walls. The walls are made of 2 X 4 wood studs, drywall and fibrous insulation when required. The following STC ratings and description were used to create Figure (4). [Ref 3]

STC 60 TWO ROWS WOOD STUDS, 6" FIBROUS INSULATION, 2 LAYERS 1/2" DRYWALL BOTH SIDES

STC 55 TWO ROWS WOOD STUDS, 6" FIBROUS INSULATION, 1 LAYER 1/2" DRYWALL BOTH SIDES

STC 50 2 X 4 STUDS, 3 1/2" FIBROUS INSULATION, 2 layers 1/2" DRYWALL, ONE SIDE RESILIENT CHANNEL W/ DWL. OTHER

STC 45 2 X 4 STUDS, 3 1/2" INSULATION, 1/2" DRYWALL, ONE SIDE RESILIENT CHANNEL W/ 1/2" DWL. OTHER

STC 38 2 X 4 STUDS, 3 1/2" FIBROUS INSULATION, 1/2" DRYWALL BOTH SIDES

Figure (4) shows that it costs $5.83 per square foot to build a wall assembly rated STC 38, while it costs $11.62 per square foot to build a wall assembly rated STC 60. Desired NAVFAC STC rating of STC 55 costs $10.64 per square foot. The STC 38 rating represents poor acoustic protection for exterior walls while STC 60 represents better protection than the NAVFAC desired level. STC 60 however, does not

represent a level of protection that meets or exceeds the end users needs. The cost per square foot figures were determined using the 1989 Means Residential Cost Data, published by R. S. Means Company, Inc.

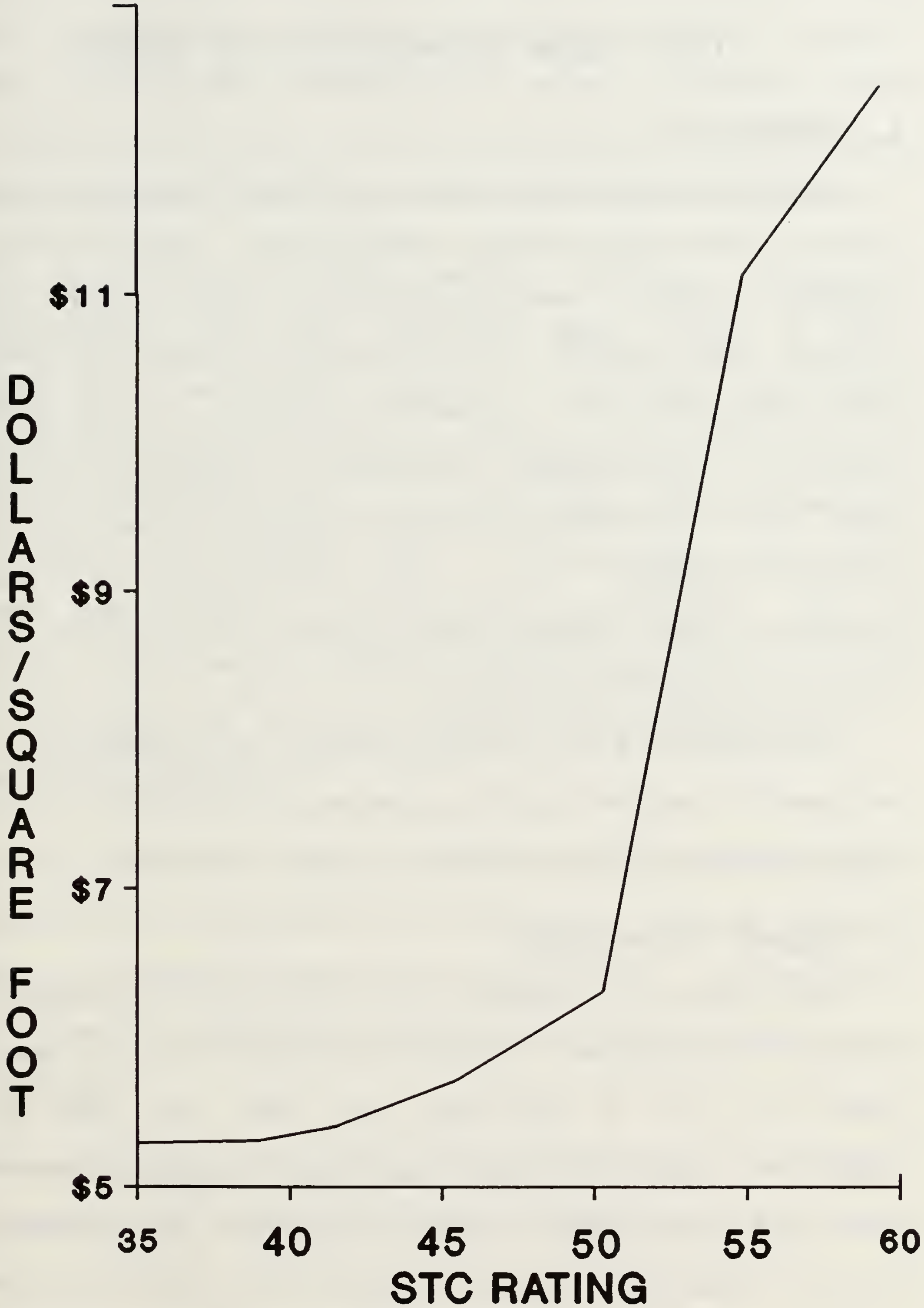


Figure 4
Sound Transmission Class

III. DESIGN PROCEDURES FOR DOD HOUSING

A. BACKGROUND

NAVFAC currently provides new family housing by a method known as One-step Turnkey construction. Under this method, proposers offer a design and a price for a family housing project. The proposer is responsible for both the design and the construction of the housing units, if the design is accepted. The proposals are based on a Request for Proposal (RFP) which contains performance specifications and specific design criteria. Once the contractor's proposals are received, NAVFAC reviews the proposed construction drawings for compliance with the RFP.

The purpose of the Turnkey process is for NAVFAC to select and award a contract to the proposal that is found to be most advantageous to the government. [Ref. 8 and 13]

B. REQUEST FOR PROPOSAL

The Request for Proposal is a bound set of documents that provides the proposer a scope of what work is to be completed, where it will be performed and when the work will be completed. The RFP is usually broken down into five sections, which are subdivided into many activities (See Appendix E).

Part I-Acquisition Requirements - briefly describes the work, the applicable Federal Acquisition contract clauses, labor provisions, topographical maps indicating site location, soil borings, existing facilities and utilities, financial constraints, insurance and bidding requirements.

Part II-Technical Requirements- outlines specific requirements that the contractor must focus on when designing a particular project. It lists applicable standards to ensure sound construction practices, like the National Electrical Code and National Fire Protection Association Life Safety Code. It discusses particular issues that pertain to construction disciplines, such as minimum size of rooms, certain construction materials that can and cannot be used, tolerances and specifications for component hardware.

Part III-Contractor Quality Control- outlines the minimum personnel the contractor must have to perform quality checks on certain construction disciplines. It addresses what type of testing is required and how many are to be performed.

Part IV-Submission Requirements-briefly summarizes what submittals are required of the contractor, when the submittals are to be forwarded to the government and who will approve and reject the submittals.

Part V-Technical Evaluation- this informs the contractor what the government will be evaluating during the technical evaluation board. Areas such as unit livability, maintainability and energy performance are reviewed.

While the five parts are important to the contractor, this thesis only reviews Part's II and V. Part II is briefly reviewed because this is the first and the only time that the government makes a potential proposer aware that acoustical specifications are required in the design of the particular project. Part V, the Evaluation process, is addressed in the following chapter.

C. TECHNICAL REQUIREMENTS-ACOUSTICS

The technical requirements section of the RFP is broken down into many different activities. (See Appendix E) This thesis reviews the Dwelling Unit Design Area which provides specific guidance to the contractor. Unit Design Area is defined as usable space that is occupied by the end user. Examples of these spaces are bedrooms, bath rooms, living rooms and kitchens. This part of the RFP provides specific requirements for certain areas. An example of this is the bedroom. A generic specification or requirement for a bedroom may be as follows: [Ref. 13:pp. 2-21 and Ref. 14]

1. Bedrooms

a. General: Bedrooms shall be designed to accommodate a king size bed in master bedrooms and twin beds in other

rooms. Privacy, both visual and acoustic, is required (i.e.. use of closet, bathroom, and/or sound insulation) between adjacent bedrooms and also between sleeping and living areas (i.e.. living/dining, kitchen/family, ect.) Window, door, and closet placement should enhance furnishability.

b. Emergency Egress: Bedroom emergency egress shall comply with requirements of NFPA 101.

It is only in Part II of the RFP that acoustical attenuation is addressed. In order for the contractor to prepare a bid and to determine what type of materials to use, (i.e., bedroom and surrounding rooms) the RFP identifies sound attenuation for floor-ceiling and wall systems. [Ref 13:pp. 2.25-2.28 and Ref. 14:pp.2.23-2.24] A generic RFP will identify sound attenuation criteria as follows:

2. Floor Systems

a. Party Floor: Ceiling systems: Party floors shall have a topping slab of 1 1/2" lightweight concrete, 'gyp-crete', or similar material. Party floors shall have minimum one-hour fire resistance rating in accordance with ASTM E119. Floor-ceiling construction between dwelling units (party floors) shall be designed to provide the following sound transmission ratings in accordance with ASTM E90 and E492.

Sound Transmission Class	STC-52
Impact Isolation Class	IIC-60

Floors between dwelling units and garages shall have an STC rating of 50. [Ref. 13:pg. 2-23 and Ref. 14:pg. 2-26]

3. Wall Systems

a. Party Wall System: Walls separating dwelling units (party walls) shall provide one-hour or two-hour separation as required by applicable code, extending from foundation to the underside of roof sheathing, and provide a minimum sound attenuation rating of STC-55, as determined in accordance with ASTM E90. Walls between dwelling units and garages shall have STC rating of 50. [Ref. 13:pp. 2-27 and Ref. 14:pg. 2-24]

The sound attenuation criteria contained in the RFP is drawn from the Military Handbook 1035, Family Housing, dated 15 June 1989. Once the sound attenuation criteria as well as other specifications are outlined for the potential proposer, it is up to the contractor to prepare designs and bidding documents that are in accordance with the RFP's specifications and referenced building codes and manufacturing practices. In the case of designing for sound attenuation, a contractor may go to a variety of sources that show details for floor, ceiling, and wall construction that meet the design criteria. Architectural Graphic Standards, publications from the Gypsum Association and Sweets Catalog provide a proposer good generic information that can be used to satisfy the RFP's design requirements. [Ref. 21]

After the proposer's bid documents and design is forwarded to NAVFAC, a Technical Evaluation Board (TEB) is established to evaluate the contractors design and bid. The next chapter reviews the government's process of evaluating the contractors' design against the RFP with respect to acoustical attenuation.

IV. ACOUSTIC REVIEW PROCEDURES OF CONTRACTOR PROPOSALS FOR DOD HOUSING

A. BACKGROUND

In order to be considered during the design selection process, contractors are required to submit design packages and pricing information as outlined in the Request for Proposal. The design package, and pricing information is sent to a specified Engineering Field Division where the pricing information and the design package are separated from one another. The design package which includes technical information about the scope of work, is forwarded to the Chairman of the Technical Evaluation Board (TEB). The TEB, using the Technical Evaluating Manual as a guide, evaluates the contractor's proposal, and establishes a quality rating (e.g., outstanding, satisfactory) and ranks all proposals by order of technology. (e.g., Proposal 109 is ranked third out of nine submitted proposals). [Ref. 13:pg. 6]

B. PURPOSE OF TEB

The purpose of forming a Technical Evaluation Board is to ensure that the proposals submitted by contractors are fairly reviewed by more than one party to determine if the material submitted is in compliance with standards and specifications outlined and referenced in the RFP. After the review of all designs is complete, the Board recommends which design should

be awarded based only on the technical aspects reviewed. The extent of the review is in proportion with the amount of information required from the proposals and the extent of the requirements specified in the RFP.

After the Board ranks the proposals, the Board then calculates a Cost/Quality ratio (i.e. dollar cost divided by quality points), assuming compliance with contractual features of the proposal. It then selects and recommends a proposal for award based on cost and technology. [Ref. 20] "The selection is normally on the basis of lowest cost/quality ratio, however, sound judgement is applied in the final selection of a proposal to ensure that cost and other factors are properly considered in making an award in the governments best interest." [Ref. 20:pg. 4-3]

1. TEB Composition

The selection board is comprised of responsible personnel of an Engineering Field Division with advisors from Naval Facilities Engineering Command, Washington, DC. The TEB members are highly qualified representatives of the assigned functional areas (e.g., civil engineering). Below is a list of positions that might be assigned to a housing Technical Evaluation Board for a contract assigned to Western Division, Naval Facilities Engineering Command, located in San Bruno, California. [Ref. 23]

Members
WESTNAVFACENGCOM Chairperson Code 040H.4
WESTNAVFACENGCOM Architect Code 040H
WESTNAVFACENGCOM Architect Code 040H

WESTNAVFACENGCOM Mechanical Engineer Code 040H
WESTNAVFACENGCOM Installation Representative
WESTNAVFACENGCOM Housing Representative Code 08
(Consultants if required)

Advisors
WESTNAVFACENGCOM Electrical Engineer Code 040H
WESTNAVFACENGCOM Civil Engineer Code 040H
COMNAVFACENGCOM National Team Advisor Code 05

When the TEB reviews a contractor's proposal, each functional area (e.g., unit design, site design) is evaluated by at least two members of the board. This allows different individuals familiar with the functional area to review each factor from a different perspective and provides for a more thorough evaluation of the contractor's proposal. When a contractor proposal is received, the TEB is required to complete the evaluation within 12-15 working days. Because of the short time frame, EFD's have the option of hiring independent consultants to provide assistance in the evaluation process.

C. FUNCTIONAL AREAS REVIEWED BY THE TEB

As previously discussed, the Technical Evaluation Manual outlines what functional areas the TEB must evaluate when reviewing a proposal. There are presently four areas that must be reviewed. The members of the board will take one of the four categories, such as Site Design, review the site design requirements that are outlined in the RFP and evaluate the proposal to determine if the contractor met the minimum requirements of the RFP. After the review, the Board will assign a point rating as outlined in Appendix F for that

particular function and perform a review of the next functional area. The four functional areas combined will total 1000 points. Appendix F also lists the four functional areas and their sub categories that are considered during the review. The four functional areas that are outlined in the Technical Evaluation Manual are: [Ref. 20:pp. 4.4-4.14]

> **Site Design**-"This area of evaluation includes overall planning, layout, design and development of the housing site(s). It embraces considerations of community appearance, compatibility of grounds and buildings, solar orientation, functionality and livability. Generally, excluded are considerations of the relative quality of materials, with the exception of landscaping, which includes numbers, types and quality of planting other than ground cover." Maximum 200 points
>
> **Site Engineering**-"This area is limited to consideration of quality of materials and engineering aspects of operation and maintenance, unless otherwise specifically indicated. Utility systems are to be evaluated up to the five foot line of the housing units. Layout and design considerations for utility systems are evaluated under site design." Maximum 100 points
>
> **Dwelling Unit Design**-"The factors and elements considered herein deal with the planning and design of the dwelling units, as opposed to durability of the materials and engineering considerations. Considerations are given to (1) the interaction of the individual housing unit to people, (2) the amenities associated with livability. These latter include such items as separation of activities, convenience, orderliness, logistics, leisure, bathing, food handling and sleeping, (3) the overall aesthetics of the housing unit and (4) the degree to which the unit blends with those outdoor features of living normally associated with (specific site(s) name)." Maximum 500 points
>
> **Dwelling Unit Engineering and Specifications**-" Dwelling Unit Engineering and Specifications will evaluate the quality of the proposed construction materials and equipment and the technical adequacy of the engineering features and product specifications including energy conservation characteristics." Maximum 200 points

1. Acoustic Areas Identified By RFP And Reviewed By Teb When Conducting Evaluation Of Four Functional Areas

The TEB is responsible for reviewing various specifications and standards that specify minimum acceptable requirements for a dwelling unit. One area that is minimally addressed in the RFP process is acoustic factors. Acoustic factors, while not specifically addressed in the evaluation manual as a functional area, is addressed by integrating known RFP requirements into a functional area. An example of this is the Dwelling Unit Design function. As defined in the above section, the unit design includes items such as separation of activities, sleeping and amenities associated with living. The definition, however, does not specifically address the relationship with acoustic protection. It is here that the TEB must review the RFP to determine how areas like bathroom design, bedroom design, floor and wall systems with acoustic requirements relate back to the Dwelling Unit Design functional area. Because the Technical Evaluation Manual is not explicit on what categories should be reviewed when discussing acoustic suppression, the evaluating process tends to let the evaluator define the priority of acoustic needs verses the need to review for constructibility and appearance.

While acoustic protection is but one small item in the evaluation process, [Ref. 23] the TEB is still supposed to review the items identified in the RFP. The following list of acoustic concerns is generated from a review of various RFP's. [Ref. 14 and 20] The list identifies areas that are

specifically identified as acoustic requirements. Many other areas in the RFP have potential or specific acoustic characteristics, but are not identified on this list because acoustic considerations are not their primary purpose. Examples of these are pipe penetrations in walls or floors, or flexible tubing on vibrating equipment. If not properly addressed for acoustics, sound transmission in the form of tapping, airborne sound or vibration can travel from one room to another.

2. RFP Items Required To Be Reviewed By TEB

1. **Bedrooms**-Privacy, both visual and privacy is required. (i.e. use of closet, bathroom and/or sound insulation) [Ref. 13:pp. 2-21]

2. **Medicine cabinets**- recessed wall cabinets are prohibited in party walls.

3. **Floor System**- Party wall/Ceiling system: Design in accordance with ASTM E90 and E 497, STC-52, IIC 60 [Ref. 13: pg. 26]

4. **Wall System**- Party wall: design with minimum sound attenuation rating of STC-55 in accordance with ASTM E 90. [Ref. 13:pg. 27]

5. **Entrance Doors**-1-3/4" thermal metal/ solid core wood. STC 30 minimum. [Ref. 24] [Ref. 13:pg. 30]

6. **Electrical Panels**- prohibited in fire/sound rated walls.

7. **Plumbing/HVAC**-shall include design provisions such as location, enclosure and acoustic treatment to minimize transmissions of noise generated by equipment. [Ref. 25:pg. 33]

V. CONCLUSION

This thesis was undertaken to examine the Naval Facilities Engineering Command's existing acoustic design practices for Navy Family Housing construction projects. The approach to this task was to first examine why NAVFAC uses acoustic suppression requirements, and amends the existing building codes to provide the same protection to all its users. This was followed by an examination of the subscribers and users of the Turnkey process. This enabled an analysis of the perceived effectiveness of NAVFAC's acoustic suppression process. Conclusions from this analysis are discussed and recommendations are identified in the chapter.

A. SUMMARY

Based on the analysis of the Naval Facilities Engineering Command's acoustic suppression process for family housing, it is concluded that NAVFAC requires noise suppression standards in all DOD housing construction in the form of a base line building standard. The standard of STC 55 for party walls and IIC 60 for party floor-ceiling assemblies exceed those specified in the Uniform Building Code. It appears that NAVFAC requires more stringent standards because, (1) of the increase in noise environment, and (2) the lack of information and emphasis placed on the subject by the Uniform Building Code.

This thesis did find that the Naval Facilities Engineering Command does require standards that exceed the Uniform Building Code, and there are design manuals and handbooks which discuss acoustic protection. It is concluded, however, that NAVFACENGCOM should do further research on the recommendations made regarding the improvement of the Turnkey process, and provide additional acoustic protection in the design and construction of housing units.

B. RECOMMENDATIONS

There are five recommendations for the Naval Facilities Engineering Command to consider. These issues are incorporated into three areas.

1. General

This thesis found a discrepancy between the determination of the new housing locations Level Day Night (Ldn) rating expressed in decibels and the sound transmission class rating of the exterior wall of a dwelling unit. When the Ldn level is determined during the creation of the base master plan phase, there is no reference to an equivalent of California Administrative Code's interior CNEL level for any rooms like the bedroom in the RFP specifications. It is recommended that NAVFACENGCOM implement a practice similar to this California code because it requires designers to consider not only external environment noise, but also internal generated noise from within the dwelling unit. The designer would be required to address the noise levels of home

appliances, and this would change the acoustic design of all interior walls, floor-ceiling assemblies and ceilings.

Research should also involve determining which STC and IIC ratings provide the end user the most benefit at the least cost marginal cost to the customer and government. Conversations with WESTNAVFACENGCOM personnel indicates that all party walls and floor-ceiling assemblies in dwelling units are designed for STC 55 and IIC 60 to provide all users the same benefit. No empirical data or support however, could be provided to determine why a rating of STC 55 is more cost beneficial to the government than say a rating of STC 60. A study should be initiated to determine how much a resident, or in this case the government, is willing to pay in order to receive additional protection from social externalities. With the increasing use of home appliances and light weight materials, the present STC 55 and IIC 60 ratings might be considered inadequate protection for present and future noise suppression.

2. RFP Process

This study found that the general wording of the RFP did not point out to the conractor the importance of acoustic protection during the Turnkey design process. A review of various RFP's indicate that the government does not view acoustic protection to be a major item or concern, and a contractor involved in the Turnkey process should focus not only on constructibility and esthetics, but also energy

efficiency and reduced maintenance. The areas of energy reviews and reduced maintenance considerations are further outlined for the contractor during the design evaluation process, but at best there is only slight emphasis placed on acoustic needs.

3. TEB Review Phase

This study found that a discrepancy also existed between the Technical Evaluation Board (TEB) review procedures for acoustic reviews and the intent of NAVFACENGCOM. In discussions with WESTNAVFACENGCOM personnel, the review of contractor housing designs with respect to acoustic suppression characteristics is only given slight emphasis. [Ref. 23] When a designer submits a design and states that the design meets all specified STC ratings, it appears that the reviewing members on the TEB will assume acoustic compliance is adequate and not review acoustic suppression on the level it requires.

One way to provide a full scale acoustic review is to use of an acoustic consultant. NAVFACINST 11101.85 highly recommends consultants as members of the TEB. It appears from discussions with WESTNAVFACENGCOM that acoustic consultants who have participated as TEB members have reviewed designs for chapels, theaters and auditoriums, because acoustics were considered a critical element in the design phase. It is recommended that NAVFAC use of consultants in the TEB phase for acoustic review as well as for other critical elements.

If this is not cost beneficial to the government, the other alternative is to require the contractor to have an independent acoustic consultant review the design and provide the government a report along with the proposal. The report would tell the government what the consultant reviewed and the consultant would have to certify that the housing design meets or exceeds the intent and specifications in the RFP.

The final recommendation concerns the format and content of the TEB evaluation manual. It is recommended that this manual be revised to include either an additional functional area which addresses external an internal acoustic requirements, or insert definite acoustic review procedures and criteria for each of the existing functional areas. The present manual implies acoustic review, a in the bedroom area, but the manual does not tell the Technical Evaluation Board what in particular to look for and consider. This manual should have a check off list of items to be reviewed, such as acoustic caulking for pipe penetrations, flexible tubing for vibrating appliances, and buffer areas between units and external noise sources like airports. The basic check list should include factors like these as well as general criteria like the ones identified in NAVFACENGCOM's Design Manual 1.03, Architectural Acoustics dated May 1985. This check list could be inserted into the RFP to indicate that the government is serious about acoustic suppression, just like it is about

energy efficiency. Some examples of the type of questions that need to be addressed in the general check off list are:

a. Building Layout

1. considering the external noise level has been determined, (Ldn or CNEL) have noise-generated and noise sensitive spaces been identified? What are they?
2. Has building layout been responsible to various building functions?

b. Mechanical Equipment

1. Has equipment been located and evaluated for noise level?
2. Has noise control been incorporated into building design for the equipment? How?

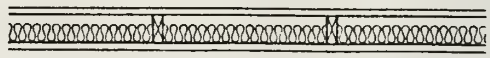
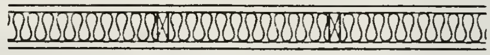
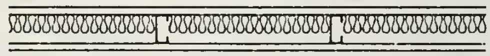
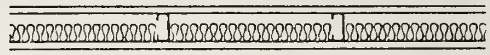
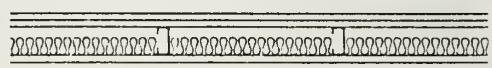
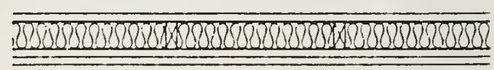
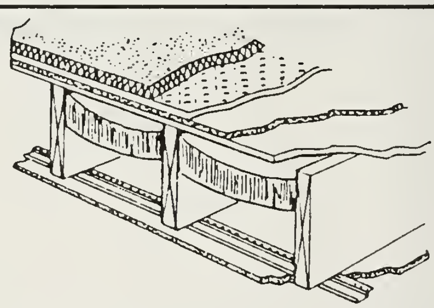
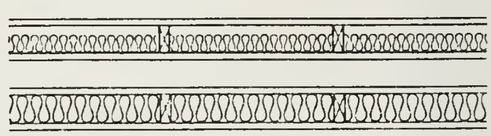
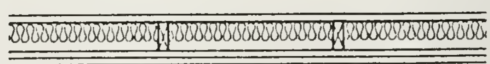
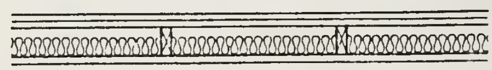
c. Plumbing

1. Have plumbing noises been identified?
2. Has design been responsive to plumbing noise problems? How?

APPENDIX A
ASTM STANDARDS

E 492-90:	Standard Test Method for Laboratory Measurement of Impact sound Transmission Through Floor Assemblies Using the Topping Machine
C 634:	Terminology Relating to Envision mental Acoustics
E 90-90	Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions
E 413-87	Classification for Rating Sound Insulation in Building
E 336-90	Test Method for Measurement of Airborne Sound Insulation in Building
E 989-89	Standard Classification for Determination of Impact Insulation Class (IIC)
E 596	Method for Laboratory Measurement of the Noise Reduction of Sound - Isolating Enclosure

APPENDIX B
SOUND TRANSMISSION CLASS ASSEMBLIES

Single wood studs 24˙ o.c., single layer ½" type X gypsum board each side, 1½" Sound-Pruf™ in stud cavaties.	47	
Single wood studs 24" o.c., single layer ½" type X gypsum board on one side, single layer ⅝" type X gypsum board on opposite side, stud cavaties filled with Sound-Pruf.™	48	
Single steel studs 16" o.c., single layer ½" type X gypsum board on one side, single layer ⅝" type X gypsum board on opposite side, stud cavities filled with Sound-Pruf.™	47	
Single wood studs 16" o.c., single layer ½" type X gypsum board on one side, single layer ⅝" gypsum board on opposite side, stud cavities filled with Sound-Pruf.™	42	
Single steel studs 16" o.c., single layer ½" type X gypsum board on one side, single layer ⅝" type X gypsum board on opposite side, 1½" Sound-Pruf™ in stud cavities.	38	
Single wood studs 16" o.c., single layer ⅝" type X gypsum board each side, stud cavities filled with Sound-Pruf.™	44	
Single steel studs 16" o.c., single layer ½" type X gypsum board each side 1½" Sound-Pruf™ in stud cavities.	43	
Single steel studs 16" o.c., single layer ½" type X gypsum board on one side, double layer ½" type X gypsum board on opposite side, 1½" Sound-Pruf™ in stud cavities.	45	
Single wood studs 16" o.c., single layer ⅝" type X gypsum board on one side, double layer ⅝" type X gypsum board on opposite side, stud cavities filled with Sound-Pruf.™	47	
Floor Panel, single 2" x 10" floor joists 16" o.c., ½" waferboard sub-floor, ½" particle board main floor, carpet, pad, single layer ⅝" type X gypsum board mounted on resilient channels, 2" Sound-Pruf™ sprayed in joist cavities.	54	
Same as above but 1" Sound-Pruf™ instead of 2".	45	
Double wall, single layer ½" type X gypsum board on each side of single wood studs 24" o.c., 1½" Sound-Pruf™ in stud cavities, 1" air gap, single wood studs 24" o.c., single layer ½" type X gypsum board on one side, single layer ⅝" type X gypsum board on opposite side, stud cavities filled with Sound-Pruf.™	61	
Single wood studs 24" o.c., single layer ½" type X gypsum board on one side, mounted on resilient channels, single layer ⅝" type X gypsum board on opposite side, stud cavities filled with Sound-Pruf.™	54	
Single wood studs 24" o.c., single layer ½" type X gypsum board on resilient channels on one side, single layer ½" type X gypsum board on opposite side, 1½" Sound-Pruf™ in stud cavities.	52	
Single steel studs 16" o.c., single layer ⅝" type X gypsum board on one side, single layer ½" type X gypsum board mounted on resilient channels on opposite side, stud cavities filled with Sound-Pruf.™	53	

APPENDIX C
REQUEST FOR PROPOSALS

SMO:TAM:021.1E1

STANDARD FORM 20 (Modified)
JANUARY 1961 EDITION
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.401

REQUEST FOR PROPOSALS
(CONSTRUCTION CONTRACT)

REFERENCE

Request for Proposals
N62474-84-R-4636

DATE

30 AUGUST 1985

NAME AND LOCATION OF PROJECT

100 FAMILY HOUSING UNITS
AT THE
NAVAL AIR STATION
ADAK, ALASKA

DEPARTMENT OR AGENCY

Department of the Navy
Naval Facilities Engineering Command

BY (Issuing office) Western Division
Naval Facilities Engineering Command
P. O. Box 727
San Bruno, California 94066-0720

Proposals in quantities specified in Paragraph 1C.3, Page 1-18 for the work described herein will be received until 2:30 P.M., Local Time, 25 October 1985 at the Western Division, Naval Facilities Engineering Command, Building 208, First Floor, San Bruno, California.

CAUTION: Late Proposals - See the special provisions in this request for information related to late proposals.

DESCRIPTION OF WORK:
Design and construction of 100 family housing units in Government-owned land, complete with all required utility services, roads, walks, grading, drainage, and other site improvements as necessary to provide a complete and usable facility in accordance with furnished criteria.

1. NOTE THE AFFIRMATIVE ACTION COMPLIANCE REQUIREMENTS FOR CONSTRUCTION CLAUSE OF THIS SOLICITATION.
2. NOTE THE CERTIFICATION OF NONSEGREGATED FACILITIES IN THIS SOLICITATION. Bidders, Offerors, and Applicants are cautioned to note the "Certification of Non-segregated Facilities" in the solicitation. Failure of a bidder or offeror to agree to the certification will render his bid or offer nonresponsive to the terms of solicitations involving awards of contracts exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity Clause. (1978 SEP)
3. AFFIRMATIVE ACTION FOR DISABLED VETERANS AND VETERANS OF THE VIETNAM ERA. Offerors should note that this solicitation includes a provision which will be included in the contract requiring the listing of employment openings with the local office of the State employment service system if the award is for $10,000 or more.
4. NOTE: This project has been identified as a potential FY 86 MILCON project Congress has not yet authorized or provided an appropriation for this project. The Government's obligation hereunder is contingent upon the authorization and appropriation of funds by the Congress and the receipt of those funds by the Contracting Officer. Absent such authority and appropriation, no award will be be made and this Request for Proposals may be cancelled.
5. PREPROPOSAL CONFERENCE: A Preproposal Conference will be convened at the Western Division, Naval Facilities EngineeringCommand, 900 Commodore Drive, San Bruno, California, in the Navy and Marine Corps Reserve Center commencing at 1:00 P.M., Local Time, 11 September 1985. Attendees at this conference will be briefed concerning the Turnkey concept and will be afforded the opportunity to present questions concerning this project. Please advise this Command if your firm desires to participate in the Preproposal Conference.

This Request for Proposals is comprised of the attached Specification No. 12-84-4636 and all attachments thereto listed in Section 1A.2.

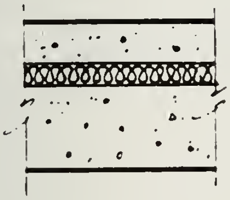
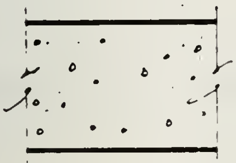
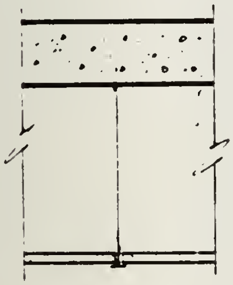
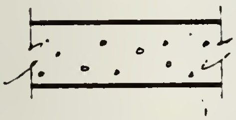
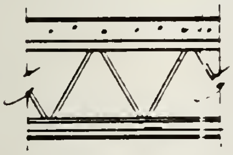
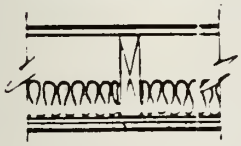
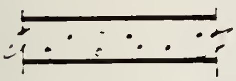
FALSE STATEMENTS IN PROPOSALS: Proposals must set forth full, accurate, and complete information as required by this Request for Proposals (including attachments). The penalty for making false statements in proposals is prescribed in 18 U.S.C. 1001.

NOTE: AWARD MAY BE MADE TO A FIRM OTHER THAN THAT SUBMITTING THE LOWEST PRICE.

THIS PROJECT IS SUBJECT TO CONTRACTOR QUALITY CONTROL PROVISIONS.

Pursuant to 10 U.S.C. 2304(g), the Government may award a contract based on initial proposals received, without discussion. Accordingly, initial proposals should be submitted on the most favorable terms, from a price and technical standpoint, which the offeror can submit to the Government.

APPENDIX D
FLOORS AND STC AND IIC RATINGS

	STC 73 IIC 72	4" FLOATING SLAB 2"-3# FIBERGLASS OR ELASTOMERIC MOUNTS 8" CONCRETE SLAB
	STC 61 IIC 40/IIC 70 W/ CARPET & PAD	12" CONCRETE SLAB
	STC 60 IIC 40/IIC+75 W/ CARPET & PAD	6"CONCRETE SLAB 16" AIR SPACE W/ LAY-IN CEILING
	STC 55 IIC 34/IIC 70 W/ CARPET & PAD	6" CONCRETE SLAB
	STC 54 IIC 35/IIC 70 W/ CARPET & PAD	3" CONCRETE TOPPING BAR JOIST 1/2" DRYWALL ON METAL CHANNELS
	STC 50 IIC 45/IIC 65 W/ CARPET & PAD	3/4" T&G PLYWOOD JOISTS 3 1/2" FIBROUS INSUL. RESILIENT CHANNELS 1/2" DRYWALL
	STC 50 IIC 25/IIC 70 W/ CARPET & PAD	4" CONCRETE SLAB
	STC 37 IIC 32/IIC 67 W/ CARPET & PAD	3/4" T&G PLYWOOD JOISTS 1/2" DRYWALL

APPENDIX E
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APPENDICES

APPENDIX F
STANDARD TECHNICAL EVALUATION MANUAL

4B. TECHNICAL EVALUATION FACTORS:

4B.1 SITE DESIGN: MAXIMUM 200 POINTS

This area of evaluation includes overall planning, layout, design and development of the housing site(s). It embraces considerations of community appearance, compatibility of grounds and buildings, solar orientation, functionality and livability. Generally, excluded are considerations of the relative quality of materials, with the exception of landscaping, which includes numbers, types and quality of planting other than ground cover.

a. SITE UTILIZATION AND DEVELOPMENT: 1-50 POINTS

The project density in living units per gross acre is pre-established by the Project Scope and Composition (number of units and number of bedrooms). Within this pre-established parameter, elements of site design to be evaluated include:

1. STREET AND BLOCK PATTERN

2. STRUCTURE GROUPING AND VARIATIONS

3. STRUCTURE ORIENTATION

   With respect to the prevailing winds, views, and taking into account the climatic conditions in the area.

4. BUFFERING, PRIVACY AND OPEN SPACE

b. SITE INTEGRATION: 0-10 POINTS

Integration of physical flows and relationships between the site and surrounding region. Continuity and compatibility of systems, patterns and aesthetics. (The transition between old and new.) Evaluation of compatibility with surrounding environment should consider relationship of development to regional climate and architecture. Optimum siting should provide reasonable transitions to and from surrounding areas. Avoid visual orientations toward incompatible land use of areas.

c. STREET SYSTEM: 1-20 POINTS

1. VEHICULAR CIRCULATION

   . ACCESS AND TRAFFIC CONFLICTS

   . SERVICE VEHICLE ACCESS

2. STREET DESIGN FOR SNOW REMOVAL

d. PARKING: 1-10 POINTS

1. QUANTITY AND PROXIMITY TO DWELLING UNITS

2. DRIVEWAY/PARKING AREA LAYOUT

e. UTILITY SYSTEMS: 1-25 POINTS

Evaluate system design and layout.

1. WATER DISTRIBUTION

2. SANITARY SEWER SYSTEM

3. STORM DRAINAGE

4. ELECTRICAL DISTRIBUTION

5. FUEL OIL STORAGE AND DISTRIBUTION

f. SITE GRADING: 1-30 POINTS

This factor considers the appropriateness of proposed grading plans including, but not limited to, efficiency of the surface drainage, fill, engineering economies, slopes and gradients. Considerations of aesthetic qualities of the grading plans are addressed under Landscaping.

1. SURFACE DRAINAGE

2. FILL

g. PEDESTRIAN CIRCULATION: 1-15 POINTS

This factor concerns the way in which the walkway system performs the function of transporting pedestrians from one essential location to another.

1. TO BUILDING, PARKING AND REFUSE DISPOSAL

2. TO RECREATION AREAS, SCHOOLS, AND COMMUNITY BUILDINGS

h. GRASS GROUND COVER AND SOIL TREATMENT: 1-10 POINTS

1. TREATMENT OF SOIL

2. QUALITY/SUITABILITY OF GRASS AND GROUND COVER

i. RECREATION AREAS: 1-15 POINTS

1. MAJOR RECREATION AREAS

- An open space within a minimum dimension of 50 feet having 10,000 square feet may be considered an area for active recreation. A good plan should provide one such area for every 50 to 60 dwelling units.

2. PLAYGROUNDS AND TOT LOTS

Playground site should be 600 to 2500 square feet, while tot lots should be about 1500 to 2500 square feet.

- Number, size, location and accessibility:

- Cover/Weather Screen Tot lots.

j. ENVIRONMENT CONSIDERATIONS: 0-15 POINTS

1. PRESERVATION OF NATURAL FEATURES:

2. SITING OF BUILDINGS AND USE OF WINDBREAKS:

4B.2 SITE ENGINEERING: MAXIMUM 100 POINTS

This area is limited to considerations of quality of materials and engineering aspects of operation and maintenance, unless otherwise specifically indicated. Utility systems are to be evaluated up to the five foot line of the housing units. Layout and design consideration for utility systems are evaluated under Site Design.

a. UTILITY SYSTEMS: 1-65 POINTS

1. ELECTRICAL DISTRIBUTION SYSTEM:
(Consider Component Quality and Maintainability)

2. WATER DISTRIBUTION SYSTEM

3. SANITARY SEWER SYSTEM:

- Quality of Pipe

- System Maintainability

4. FUEL OIL DISTRIBUTION SYSTEM:

- Compatibility with existing systems, quality, and suitability of pipes, valves, pressure regulators, pressure reducing valves, etc.

5. STORM DRAINAGE SYSTEM:

- Grading for Overall Surface Runoff

- Underground System (Specifications)

6. OUTDOOR LIGHTING:

- STREET LIGHTS

- AREA/WALK LIGHTING

b. STREET CONSTRUCTION 1-10 POINTS

c. PARKING AND DRIVEWAYS 1-10 POINTS

d. RECREATIONAL EQUIPMENT: 1-10 POINTS

Playground and/or Tot Lot equipment provided by proposer. Consider quality, quantity and appropriateness of equipment.

e. ENVIRONMENTAL: 0-5 POINTS

1. Does site provide for proper control of rain runoff?

4B.3 DWELLING UNIT DESIGN: MAXIMUM 500 POINTS

The factors and elements considered herein deal with the planning and design of the dwelling units, as opposed to durability of the materials and engineering considerations. Considerations are given to (1) the interaction of the individual housing unit to people, (2) the amenities associated with livability. These latter include such items as separation of activities, convenience, orderliness, logistics, leisure, bathing, food handling and sleeping, (3) the overall aesthetics of the housing unit and (4) the degree to which the unit blends with those outdoor features of living normally associated with Adak.

a. DWELLING UNIT TYPE: 0-30 POINTS
Use the following equation:

$$\frac{\text{NUMBER UNITS EACH TYPE} \times \text{VALUE FACTOR EACH TYPE}}{\text{TOTAL UNITS}} = \text{POINTS}$$

VALUE FACTORS:

		NUMBER UNITS/BUILDING				
		1	2	3-4	5-6	7-8
EM	2 BR	5	20	30	10	0

b. EXTERIOR APPEARANCE: 0-45 POINTS

This factor considers the overall aesthetics of the building exteriors including: Variety of facades, visual effect of garages, fenestration, proportion/scale of building and building entries.

c. OUTDOOR/INDOOR INTEGRATION: 1-30 POINTS

1. Layout of facilities within the unit which enhance indoor/outdoor living. e.g., first floor egress/access of townhouse, and air-lock design.

2. Enclosed and roofed patios (consider use of materials and climatic desirability)..

3. Privacy Fencing

d. STORAGE: 1-25 POINTS

Consideration must be given to size, location and utility of all storage areas.

1. EXTERIOR BULK STORAGE

2. INTERIOR BULK STORAGE

3. CLOSET (LINEN, COAT, CLOTHING)

e. GARAGES: 0-25 POINTS

Aesthetics are considered under b. Give consideration to size and access to living units.

f. FUNCTIONAL ARRANGEMENT: 0-40 POINTS

Does the floor plan of the unit provide desirable relationships between living, food handling, sleeping and bathing areas? Does the relationship of the areas conflict with or enhance each other? Are the logistics of home operation considered (entrance to unit, furnishability, etc.)? Are the special environmental considerations considered in unit design? In all of the above, consideration must be given to the family size which dictates unit size.

g. CIRCULATION: 0-15 POINTS

1. Accessibility without disturbing other activities.

2. Ease of furniture movement (particularly at stairs & vestibules).

h. APPORTIONING OF SPACE: 0-20 POINTS

1. Maximized livability and efficiency of household functions.

i. LIVING: 1-35 POINTS

Considerations of interior design, which enhance the individual and family group aspects of recreation, leisure and entertainment. Consider window and door placements, furnishability, traffic patterns and clearances under use conditions.

1. Family Room/Secondary Dining - Add points when provided.

2. Possibilities for joint or concurrent separate activities.

j. SLEEPING: 1-35 POINTS

1. Bedroom Size (Add points for area and/or dimensions in excess of specified minimum).

2. Privacy (visual, acoustic).

3. Ceiling light fixture.

4. Furnishability.

K. BATHING: 1-15 POINTS

1. Number and Size (Add points for that in addition to minimum specified.)

2. Accessibility (guests, master bedroom)

l. FOOD HANDLING: 1-35 POINTS

It can be said that nearly all of the activities of the family group are heavily affected by the design quality of the food handling area. Considerable initiative and innovative approaches to the design of this area can be achieved to enhance this major logistics and control area. Keep in mind the additional time to be spent in this area due to adverse environment/climate considerations.

1. Efficiency

2. Storage

3. Eating/Service counter.

4. Privacy (Visual) window/door size and location.

m. UTILITY AND WORK AREAS: 1-15 POINTS

Address provision for washers and dryers and freezer in an area of the unit which provides for efficient circulation and yet does not infringe on other functions.

1. Size, layout and location (Add points for areas suitable for ironing and/or light hobby work).

n. ENERGY CONSUMPTION ANALYSIS: 0-30 POINTS

Percent energy performance limitation met by proposal:

%	less than -70	70-79	80-89	90-99	100-109	110+
Points	0	10	15	20	25	30

(NOTE: points assigned as indicated and not interpolated

o. ALTERNATIVE ENERGY SYSTEMS PERCENT REDUCTION 0-15 POINTS

(Net reduction of Baseline energy consumption analysis)

% reduction	less than -10	10-14	15-24	25+
Points	0	5	10	15

p. WINDOWS, DOORS, AND HARDWARE: 1-25 POINTS

Evaluate suitability and aesthetic qualities of proposed windows, doors, and hardware.

1. WINDOWS AND WINDOW COVERINGS

. WINDOWS (INCLUDING SCREENS)
(Consider Finishes)

. WEATHER HOODS

WINDOW COVERINGS AND FIXTURES (including insulated shades and blinds)

2. DOORS

- Interior Doors (including interior vestibule door.)

- Exterior Doors

- Garage Doors (Roll-up or Sectional)

3. HARDWARE

- Materials

- Finishes

q. CABINETS AND COUNTERTOPS: 1-10 POINTS

r. INTERIOR PLUMBING: 1-5 POINTS

1. System Layout

s. INTERIOR ELECTRICAL SYSTEM: 1-5 POINTS

Evaluate system for functional arrangement, layout, design and economies.

1. System Layout
2. Fixtures

t. HEATING AND VENTILATING 1-10 POINTS

1. System Layout

u. FINISHES: 1-20 POINTS

Evaluation shall consider the maintainability, durability, and quality of the finishes, materials and features incorporated in the items and systems offered, with particular emphasis placed on household maintainability.

1. FLOORING

2. EXTERIOR WALLS

3. INTERIOR WALLS

v. OTHER MISCELLANEOUS FEATURES: 1-15 POINTS

4B.4 DWELLING UNIT ENGINEERING AND SPECIFICATIONS: MAX 200 POINTS

Dwelling Unit Engineering and Specifications will evaluate the quality of the proposed construction materials and equipment and the technical adequacy of the engineering features and product specifications including energy conservation characteristics.

a. FOUNDATION SYSTEM: 1-15 POINTS

Evaluation shall consider the foundation system provided, quality of materials and construction details.

1. PERIMETER WALL (Crawl Space)

2. PILES

b. FLOORING SYSTEM 1-10 POINTS

c. WALLS (INTERIOR, EXTERIOR, PARTY) AND CEILINGS: 1-20 POINTS

1. CONSTRUCTION

2. INSULATION (Thermal and Sound)

3. SHEATHING

d. ROOF SYSTEM: 1-10 POINTS

Evaluation of the roof system shall address structural and quality factors, including maintenance considerations. The roof system consists of the framing system (including eaves), sheathing, roofing and flashing.

1. FRAMING

2. ROOFING AND SHEATHING

3. FLASHING

e. WINDOWS AND WINDOW COVERINGS/HARDWARE 1-25 POINTS

Windows and hardware shall be evaluated on the basis of quality of materials and maintainability.

1. WINDOWS

2. WINDOW COVERINGS/HARDWARE

3. WEATHER HOODS

f. DOORS (Including Hardware): 1-15 POINTS

Doors and hardware shall be evaluated on basis of quality of materials and maintainability.

1. EXTERIOR DOORS

2. INTERIOR DOORS

3. HARDWARE

g. CABINETS AND COUNTER TOPS: 1-10 POINTS

h. PLUMBING SYSTEM: 1-10 POINTS

Evaluate quality of materials and maintainability.

i. ELECTRICAL SYSTEM AND TELEVISIONS SYSTEMS: 1-10 POINTS

Evaluate quality of materials and maintainability.

1. FIXTURES (Corrosion resistant exterior fixtures.)

j. HEATING AND VENTILATION: 1-15 POINTS

Evaluate quality of equipment and maintainability.

k. MAINTAINABILITY: 0-35 POINTS

Consider maintenance reducing qualities of proposed materials, finishes and systems. Use of higher or quality materials and techniques to reduce repair and replacement efforts is highly desirable.

1. EXTERIOR FINISHES (WALLS, ROOF, TRIM)

2. DOORS, WINDOWS AND HARDWARE

3. INTERIOR FINISHES AND TRIM

4. BATHROOMS AND KITCHEN FIXTURES

5. UTILITY SYSTEMS INCLUDING HEATING AND VENTILATING

l. ENERGY CONSERVATION: 0-15 POINTS

1. TRIPLE GLAZING AND/OR STORM WINDOWS

2. LOW INFILTRATION WINDOWS AND DOORS

3. HIGH EFFICIENCY BOILERS

4. MISCELLANEOUS

m. APPLIANCES: 0-10 POINTS

1. Add points for appliances, and/or quality, provided over minimum specified.

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3.	ATTN: Western Division Wallace Sutherland, Code 04 Naval Facilities Engineering Command 900 Commodore Drive San Bruno, CA 94066	1
4.	Naval Facilities Engineering Command Attn: Janet M. Niederberger New Family Housing Program Manager 200 Stovall Street Alexandria, VA 22332-2300	1
5.	Professor Paul Carrick AS/Ca Naval Postgraduate School Monterey, CA 93943-5000	1
6.	William Gates, Code AS/Gt Naval Postgraduate School Monterey, CA 93943-5000	1
7.	LT James F. Stader, CEC, USN 1508 Gordon Cove Drive Annapolis, MD 21403	2

Thesis
S66987 Stader
c.1 Economic analysis of understanding and implementing design criteria for acoustic suppression in military residential units.